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HIGH-SPEED ROTARY PRINTING DEVICE
FOR AIR TRAFFIC CONTROL APPLICATIONS:
A PRELIMINARY EVALUATION

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FINAL REPORT

OCTOBER 1981

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D. C. 20590

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NOTICE
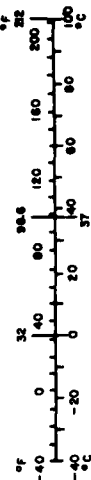
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16. Abstract

This report describes a unique, high-speed rotary printing device evaluated by the Federal Aviation Administration (FAA) Technical Center to determine potential applicability in air traffic control (ATC) work stations. The report discusses general performance of the unit, basic ATC operational problems being addressed by the study, concepts of application, and future activities for more comprehensive evaluations in simulated and real work station environments.

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in²	square inches	6.5	square centimeters	cm²
ft²	square feet	0.09	square meters	m²
yd²	square yards	0.8	square meters	m²
mi²	square miles	2.6	square kilometers	km²
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft³	cubic feet	0.03	cubic meters	m³
yd³	cubic yards	0.76	cubic meters	m³
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm²	square centimeters	0.16	square inches	in²
m²	square meters	1.2	square yards	yd²
km²	square kilometers	0.4	square miles	mi²
ha	hectares (10,000 m²)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m³	cubic meters	35	cubic feet	ft³
m³	cubic meters	1.3	cubic yards	yd³
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286. Units of Weights and Measures. Price $2.25, SD Catalog No. C13.10:286.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

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INTRODUCTION

BACKGROUND.

Under the sponsorship of Systems Research and Development Service (SRDS), a high-speed printing device design was purchased for evaluation and concept study by the Federal Aviation Administration (FAA) Technical Center as part of the Advanced Concepts Applications Program (project 219-151-130). The study was made to determine whether such a novel technology might have applications in the air traffic control (ATC) environment, especially in terminal radar approach control facilities (TRACON's) and airport traffic control towers (ATCT's).

PURPOSE.

This report describes the device as purchased; the potential ATC problems that such a device might solve; the general performance of the printer as determined by preliminary operation, study, and analysis; the concepts of application; and the planned activities to complete a more comprehensive set of tests and establish formal recommendations for use.

This document is intended to provide basic information to interested technical program managers and system designers so they may consider the potential benefits for application of this device and its technology in the ATC environment.

DISCUSSION

DEVICE DESCRIPTION.

The device purchased is a hard-copy rotary printer, model 1110-S, manufactured by SCI Systems, Incorporated, with a self-contained memory capable of storing 24 lines of characters, each line containing up to 136 characters, for a total of 3,264 characters (figure 1). On print command in several automatic modes, the memory can be printed out at the rate of 2,200 characters per second on electrosensitive, 4-inch-wide paper. The memory can also be scrolled and updated to contain only the latest set of data. Through the use of an 8080A microprocessor, numerous printing, control, and feed options can be activated. In addition, all input/ output (I/O) port activity, including handshaking and the decoding and encoding of stored program instructions, is controlled through the microprocessor. A 2,048 8-bit-word read-only memory (ROM) contains all program data, and a 4,096 8-bit-word random-access memory (RAM) stores all the printable characters, the necessary constants, and the required status words. The printer responds to 8 control codes and 128 printable characters and accepts data at baud rates of 50 to 19,200.

Physically, the printer is a cylinder approximately 4 inches in diameter and 6 inches in length. The entire unit is in a box which is 8-5/8 inches wide by 6-7/8 inches high by 13 inches deep (see figure 2) and contains electronics, power supply, printer, paper roll, controls, and several rolls of spare paper. The warranted life of the printhead is 25 million characters with an expected life of 50 million characters. Power consumption is 22 watts in the standby or data store mode and 72 watts in the printing mode.

The printer unit is, in fact, a moderately intelligent display device with a character generation and display rate of 2,200 characters per second, a refresh rate based on user demand, and a storage time of infinity. A full page of a typical video display of 1,960 characters takes approximately 0.9 seconds to produce as a hard copy. Multiple copies (up to seven) can be produced automatically, if desired.

THE BASIC PROBLEM.

The basic ATC system problem that such a device could solve is the lack of assurance for continuous data availability when needed. As more and more data are provided to the controller directly from an electronic display and less emphasis is placed on the use and generation of paper flight strips as currently used, one underlying serious concern is the sudden failure of an entire display system at a facility. A reliable, speedy, and practical system of data display (in essence, a copy of what was displayed and in use just prior to the failure), which is immediately available to and usable by the controller, could provide a means for the required transition to a safe, reduced-performance mode of operation

The problem is further compounded by a lack of space in the ATC work stations and by the cost, up to now, of special, high-performance printing or display format hard-copy machines or other types of backup devices.

A secondary problem is the loss of the presentation of printed flight data in an interim or low-level terminal operation. The present hardware for the generation of flight strips in use at terminals and many satellite airport facilities is, in reality, an application of the printer as a replacement unit for the Flight Data Entry and Printout (FDEP) device currently in use.

GENERAL PERFORMANCE.

In order to determine the basic performance characteristics and establish the advantages and disadvantages of the printer, it was operated in several modes. Initially, the unit was operated in its own internal test mode which provides for a manually started printout of 24 lines of 128 different characters per line (figure 3). This is a complete set of all possible characters and is used to

verify head alignment, paper feed uniformity, memory, central processing unit (CPU) functional performance, and printing action uniformity.

The writing head is composed of three sets of five metal wipers on the periphery of a thin drum which is approximately 4 inches in diameter (figure 4). As each set of wipers sweep past the 4-inch-wide paper (across the narrow dimension of the paper), the wipers are individually activated in time synchronism with the paper and the desired characters and dots are burned on the paper. Since there are three sets of wipers at 120° intervals, each set successively writes a full 24 rows of one column of 5- by 7-dot characters. One revolution of the head corresponds to three columns of characters. Spinning at 1,800 revolutions per minute (rpm) or 30 revolutions per second (rps), 90 columns per second are written on the 4-inch paper (figure 5).

The perceived noise level is moderate, approximately 77 decibels (dB) at 3 feet when printing; 0 dB when not printing. This is from a closed case but with the printer unit sitting on a work surface. Since print action is only expected at infrequent intervals, the noise level is not initially considered a serious problem. The characters produced are approximately 0.06 inches wide by 0.94 inches high, black on a silver-white background.

In the second mode of operation, the unit was interfaced through an Electronic Industries Association (EIA) Standard RS232-C Interface to a Model PDP-8 Computer which was driving and controlling several display devices, including cathode-ray tubes (CRT's), plasma displays, and a deformographic storage display. Each time a new display page was generated to one of the other devices, a complete, printed replica was produced on the printer (figure 6). The reproduction was usually about 4 by 6 inches in size and

was 100-percent accurate with respect to data content and data position.

In the third mode of operation used, data were manually entered via a keyboard to a display, and the contents of the display were printed out by the printer. Data can be entered directly into the printer from a keyboard, but since character and positional data had to be verified in these preliminary tests, a reference format was necessary for validation.

In the last mode tested, reduced-size and full-size replicas of actual flight strips were printed on the device. The full-size strips are approximately 1 by 8 inches and contain 7 lines of 74 character positions. Three strips per paper width were produced so that in actual operation, the printer produced three original size flight strips in 0.75 second (figure 7).

The reduced size strips are 1 by 4 inches and contain 10 rows of 31 characters, accomplished through an optional character set for printing characters upright in the short paper dimension. Approximately 2,400 of these strips per roll of paper can be expected. By special character generator design, characters could be printed either vertically or horizontally, under computer control, though this is not presently an advertized, available option.

A comparison of the unit's mechanical and electrical construction with other laboratory, commercial, and noncommercial devices indicated that it is substantially more rugged and conservatively designed than all other electromechanical devices familiar to Controller/Computer Interface Laboratory (CCIL) personnel. It is fabricated in a manner equivalent to high-quality test equipment and is comparable to military quality.

Since the mechanical design of the unit is based on only one moving part, the simplicity of the design further contributes to the expected life and realiability. Approximately 200,000 full-size flight data strips could be expected to be printed from one unit before head replacement would be necessary. It takes less than 1 minute to replace the head. The head cost is approximately $35; no ink, ribbons, etc., are used. The paper cost in small quantities is approximately $3 for a 200-foot roll (about 900 full-size flight strips) or about one-third of a cent per strip.

The unit, as purchased, costs $780 in single quantities and is also available without case, without storage memory, and as a cylinder-shaped printer mechanism alone.

In addition, a unit of similar design is sold that uses 8-inch-wide paper, prints 6,000 to 8,000 characters per second, and is, otherwise, a functionally larger equivalent of the purchased model. The only visible performance difference is that the characters are upright in the long paper dimension so that a full flight strip is printed on a 1-inch length of paper.

Electrically, the unit is equivalent in completeness, design, documentation, and state-of-the-art components to the most current lab equipment in quality, printed circuit design, and construction.

CONCEPTS OF APPLICATION.

For this report, several concepts can be described as an indication of potential applications. These concepts have not been operationally evaluated as yet, but they can serve as a basis for future studies. As such, limited depth of concept is provided.

CONCEPT 1. The printer as a reliable data source only for times of display system failure.

3

By maintaining the printer as a backup device and only using it for backup verification or during bona fide system failure, lower costs are expected, very limited space is required and failure mode integrity is assured. The rates at which printed information can be fed out of the device are very compatible with the quantities and needs during emergency conditions. The low power operation of the printer means that continually charged batteries can provide a practical power source for the printer, even during alternating current (a.c.) mains failure.

CONCEPT 2. The printer as a display device to provide formatted tabular data, graphics data with 70 lines-per-inch resolution, and other forms of data on demand.

When data changes are infrequent or data are required by the controller in a printed form, either alone or in parallel with electronically displayed data, the device can be a cost-effective method of reliable data display. This may be especially desirable during transition phases between operational system enhancements or replacements.

CONCEPT 3. The printer as a replacement for an existing printer.

Flight strip data can be maintained in its current form or condensed and printed reliably. The lack of multi-sized characters and multicolor printing does not preclude the evaluation of this device as a practical FDEP replacement or as a remote low-usage flight data printer for new interim installations.

The distribution of strips and their use in a connected set of several strips would have to be evaluated. Compared to current usage and handling, this may not be a serious problem. Determination of the advantages and disadvantages of this approach would be a part of the operational evaluation.

CONCEPT 4. The printer as a psychological "crutch," or "confidence maintainer," so that new data systems, displays, communications processors, etc., can be introduced into the ATC environment with the assurance of a highly reliable "last ditch" backup that provides data in an immediately usable and recognizable form.

The ability to evolutionize and revolutionize the ATC work station and the use of new forms of data will depend as much upon the system designer's ability to introduce new systems, devices, and software as it will depend on the controller's willingness to allow these new systems, devices, and software to be put into an operational setting. This type of printing device can provide a practical, cost-effective means of assuring the latter.

FUTURE ACTIVITIES.

Within the CCIL, various concepts will be simulated and operational utility and practicability will be evaluated.

Controllers will evaluate failure modes, handling of paper, reading and legibility of printed data, ease of markup, distributing and storing paper data, longer-term accuracy, and subjective limitations and considerations.

Within the Terminal Information Display System (TIDS) program, the use of this type of printer will be carefully evaluated in the CCIL towards inclusion in the future system design. Evaluations at this level would be concerned with device operation, ease of operation, and technical performance in a controlled pseudo-real environment.

Printers of this type will then be added to the TIDS hardware in the Technical Center's TRACON and tower cab facilities for full operational evaluation and eventual inclusion, if appropriate, in the technical data package for the major TIDS implementation.

CONCLUSIONS

The preliminary studies of the rotary printer, in the form of the SCI Systems, Inc., Model 1110-S, indicate that it is a reliable, fast, and cost-effective device which is small enough to be incorporated into near-term and advanced operational air traffic control (ATC) work stations (terminal radar approach control facilities and towers). It has the capability of providing measurable and cost-effective benefits in several ATC applications and has the potential for markedly easing problems of future display system incorporation.

RECOMMENDATIONS

1. Rotary printers should be incorporated immediately into work station designs and data display systems under study and implementation to ensure appropriate operational evaluation of the printer.

2. Further evaluations and concept studies should be conducted to determine additional applications and benefits of rotary printers in the ATC environment.

3. The activity of assuring controller confidence during system transitions should be recognized as a vital part of the human engineering process, and system design and implementation strategies that include components like the device described should be encouraged.
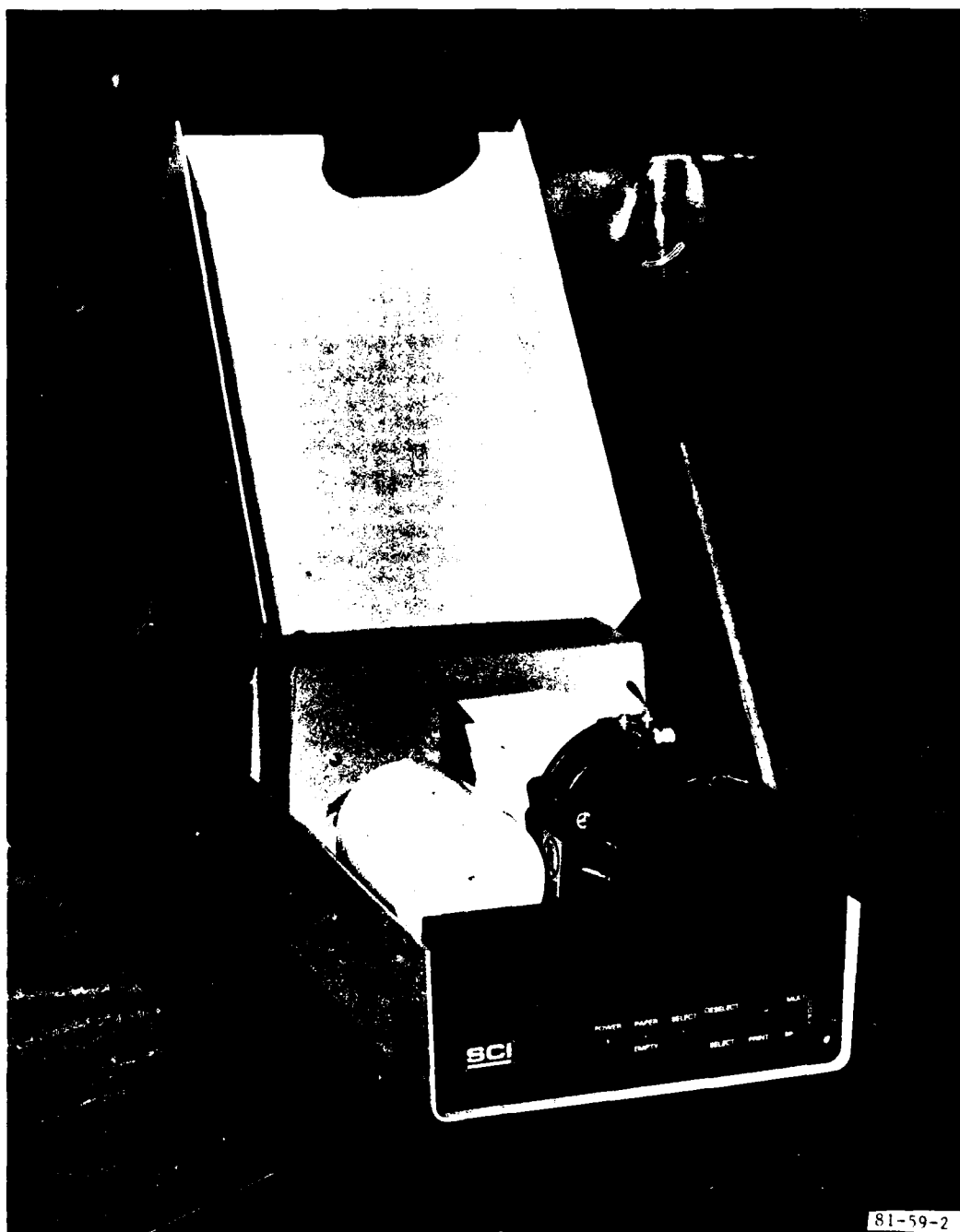
FIGURE 1.   PRINTER DEVICE — FRONT VIEW
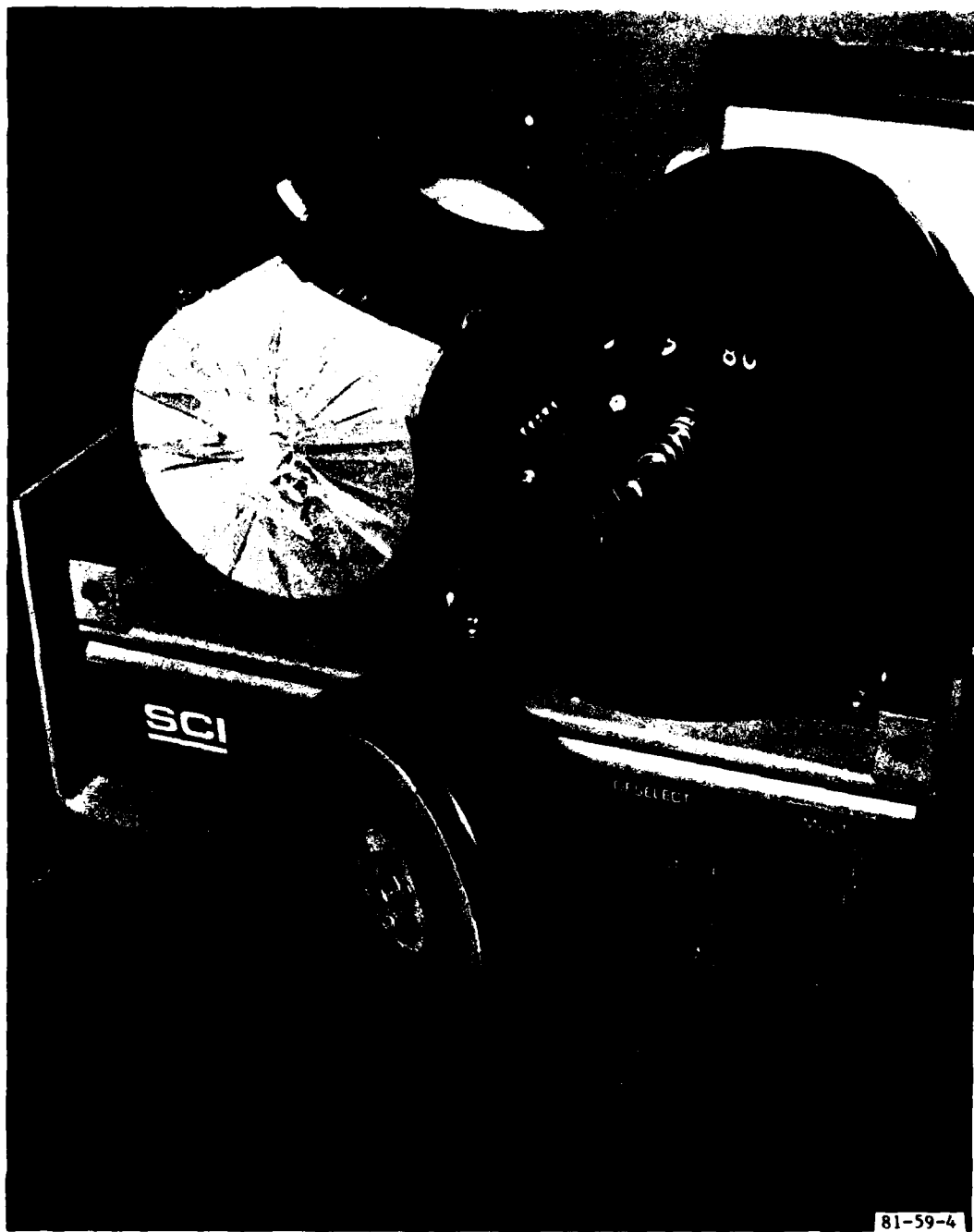
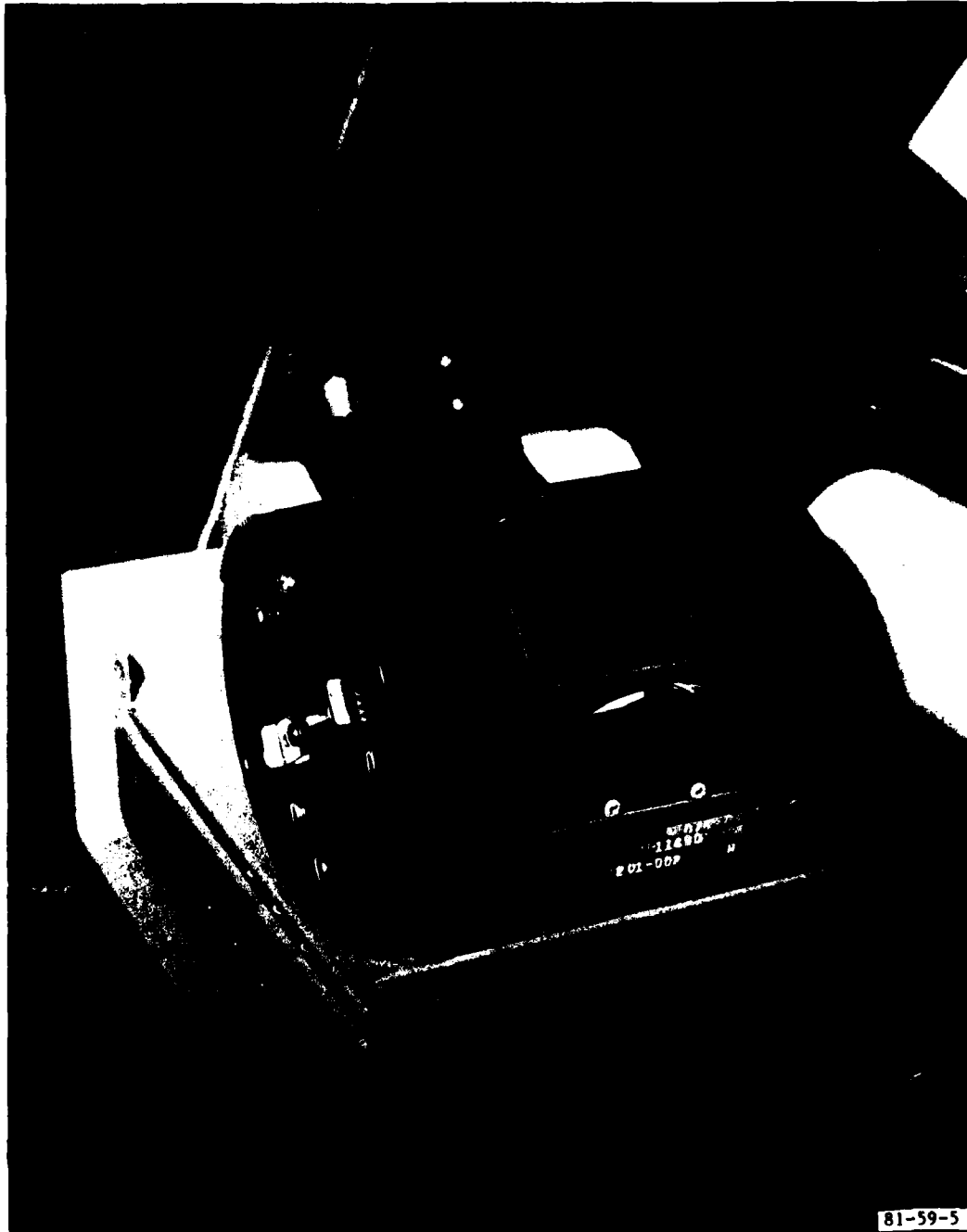81-59-1

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FIGURE 2.   PRINTER DEVICE — COVER OPEN

81-59-3

FIGURE 3.   INTERNAL TEST MODE PRINTOUT

8

81-59-4

FIGURE 4.   PRINTHEAD

FIGURE 5.   PRINTER MECHANISM — CLOSEUP VIEW

```
20:45:26 149/20/15 2990 ATIS-D
13L 6 GS      1500-1600 1800-ST-4
25R 3 ALS
06L 6 MM*                    PAGE X
*GS,ALS
15 SCT M25 OVC 1R-K 123/59 56
LOCAL TOW HEADING N.E. TO S.
IAO 2997 24L-ILS
  Q W E R T Y U I O P  7 8 9
   A S D F G H J K L  4 5 6
    Z X C V B N M  1 2 3
     [[[[[SPACE]]]]]] HOME
```

81-59-6

FIGURE 6. CRT DISPLAY PAGE PRINTED ON PAPER

```
VMR G91 1 MANTA  18  07   70                CCV V139 H20 V46 DPK
                                            V44 ACY ENO V379 OTT  0635
86 P 0225  1750                             ADW095012 NSF
HTO  95    HTO
=================================================================== CIB JF+
MMTRV 2  EWT  01  11   330   END NQA / EWT CYN WRI           1513
T542 9575                          044
279  11                           038
===================================================================
000 053/007  ACYL
DL100  2   000   58   290   BWI / 3909N/8762W
866/ A    054 15                  RBV J150 HTO J121       0521
1452 G511 031              PVD V139 HTM BOS
 56   10   1556
======= RBV
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FIGURE 7. ORIGINAL SIZE FLIGHT STRIPS

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